# Update on Merging AIRS, CrIS and IASI Level 2 Temperature and Water Vapor

**Eric Fetzer, Peter Kalmus, Hai Nguyen, Yuliya Marchetti, Evan Manning, Amy Braverman, Evan Fishbein, Bjorn Lambrigtsen, Sun Wong, Joao Teixeira and Thomas Pagano**

**Jet Propulsion Laboratory, California Institute of Technology**

**NASA Sounder Science Team Meeting**

**Greenbelt, MD**

**October 24-26, 2017**

# The Goal

**A seamless temperature and water vapor (and trace gas) product**

- **Independent of source instrument(s).**
- **Resolution, information content, etc. represented numerically.**
- **Consistent quality flagging**
  - **Or none at all.**

**For users: A web search on "NASA Sounder Temperature and Water Vapor" will point to appropriate products**

- ***NOTE*: The NRC has argued for more than one product.**

# Overview of Instruments

- **AIRS / AMSU / HSB**
  - Launched 2002.
  - Standard AIRS retrievals since 2003.

- **Two IASI / AMSU / MHS**
  - Neural net-based retrievals from EUMETSAT.
  - Bjorn Lambrigtsen and Amy Braverman (JPL) are working with Thomas August (EUMETSAT) on microwave sounder and AIRS-IASI coordination.

- **One (almost two) CrIMSS**
  - SNPP and JPSS-1 (this calendar quarter).

# Sounder Retrieval Data Sets
## *Approximately ten to be combined?*

**Mix and match any and all:**

- **NUCAPS (NOAA; Unique Combined Atmospheric Processing System)**
  - SNPP only.
- **CLIMCAPS (STC)**
  - CrIMSS
  - AIRS/AMSU possible.
- **CHARTS (GSFC STC)**
  - The AIRS standard retrieval.
  - CrIMSS also.
- **MW-only NUCAPS**
- **MW-only (JPL Lambrigtsen)**
  - All microwave sounders since 2000.
- **IDPS**
  - SNPP CrIMSS algorithm delivered at launch (?).
- **AER**
  - CrIMSS on SNPP.
- **Irion (JPL)**
  - AIRS currently.
  - Proposed for SNPP.
- **EUMETSAT**
  - Both IASA instrument neural net.
- **UW, LARC, etc.…**

# Common Formats and Consistent Products from Sounders
## *Part 2: Science Issues*


**Eric Fetzer and Evan Manning**
**Jet Propulsion Laboratory, California Institute of Technology**


**NASA Sounder Science Team Meeting**
**Greenbelt, MD**
**September 15, 2016**

**From last year**

Update: Fall 2016 Sounder STM

# Some Questions

- **How do we interpret quality flags from non-identical instruments in different orbits?**
  - **Answer: Still an open question.**
- **How do we convey vertical resolution from those different instruments?**
  - **Answer: Averaging kernels.**
- **What about uncertainties (aside from empirical estimates of relative differences)?**
  - **Answer: No systematic, consistent approach.**
- **How do clouds affect the sampling of different IR instruments?**
  - **Answer: Still TBD given different algorithm approaches.**
- ***What about fundamentally different retrieval algorithms?***
  - ***Answer: Still TBD.***

Fall 2016 Sounder STM

# *More Than Plans:*
# We are creating a data set

A Merged Temperature and Water Vapor Record from Modern Sounders

*A proposal to the Satellite and Calibration Interconsistency Studies NASA Research Announcement (NNH15ZDA001N-SCIS)*

Eric Fetzer, PI; Van Dang, Co-I; Sun Wong, Co-I; Evan Fishbein, Collaborator; Steven Friedman, Collaborator; Bjorn Lambrigtsen, Collaborator; Brian Kahn, Collaborator; Baijun Tian, Collaborator’ Qing Yue, Collaborator

Fall 2016 Sounder STM

# Relevant instruments providing temperature and water vapor retrievals (from our proposal)

| | | | | |
|---|---|---|---|---|
| **Infrared Instrument** | AIRS | IASI | CrIS | IASI |
| **Microwave Instruments** | AMSU-A, HSB | AMSU-A, MHS | ATMS | AMSU-A, MHS |
| **Agency** | NASA | EUMETSAT | NOAA | EUMETSAT |
| **Satellite** | Aqua | MetOp-A | S-NPP | MetOp-B |
| **Start Date** | 31 Aug 2002 | 19 Oct 2006 | 28 Oct 2011 | 17 Sep 2012 |
| **Equator crossing time** | 1:30 PM | 9:30 PM | 1:30 PM | 9:30 PM |
| **Orbit Period** | 98 minutes | 101 minutes | 101 min | 101 minutes |
| **Orbit altitude** | 700 km | 817 km | 817 km | 817 km |

Fall 2016 Sounder STM

# Ranking of Data Merger Challenges
## *Hard to Easy*

1. **Providing consistent Level 2 (and 3) information content from different instrument suites on separate platforms.**
   - Not something our community has done in the past.
   - Much has been done with TOVS and microwave instruments.

2. **Organizing that information in a way that is useful to ALL users.**
   - Many lessons learned already, work is underway.

3. **Implementing a common data format.**
   - Evan Manning is organizing this for hundreds of variables.

# Data fusion overview

## *Slides provided by Peter Kalmus, JPL*

**Benefits of fusion:**

- **Data collection is often incomplete, sparse, and yields spatially incompatible results. Our goal is to infer the true process from all available data sources.**
- **Data fusion can capitalize on complementary strengths to minimize prediction errors.**

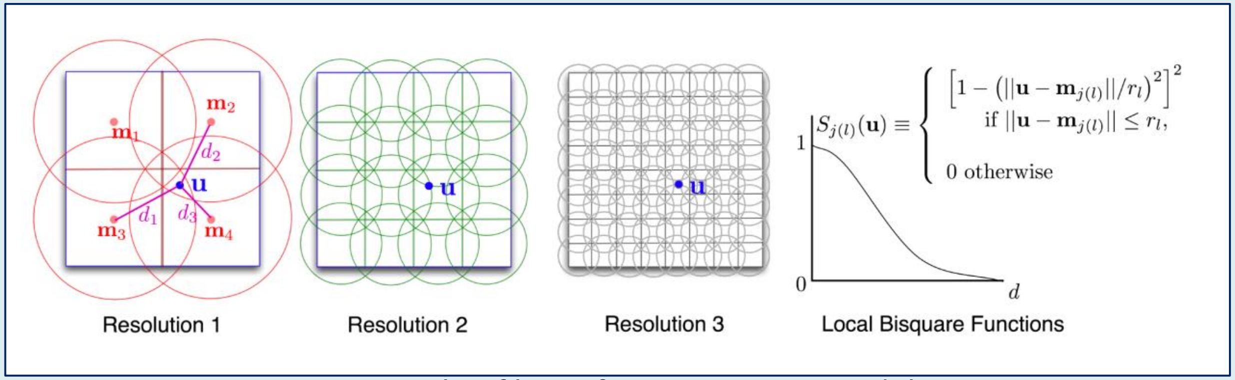
**Challenges for data fusion in remote sensing applications:**

- **Massive size.**
- **Footprint misalignment.**
- **Instrument biases.**
- **Different measurement error characteristics.**

# Spatial Statistical Data Fusion

- **Our data fusion method addresses the challenges above using a Spatial Random Effects model (SRE; Cressie and Johanneson, 2008)**

- **It models the spatial dependence using a dimension reduction technique, allowing us to apply spatial interpolation to massive datasets.**

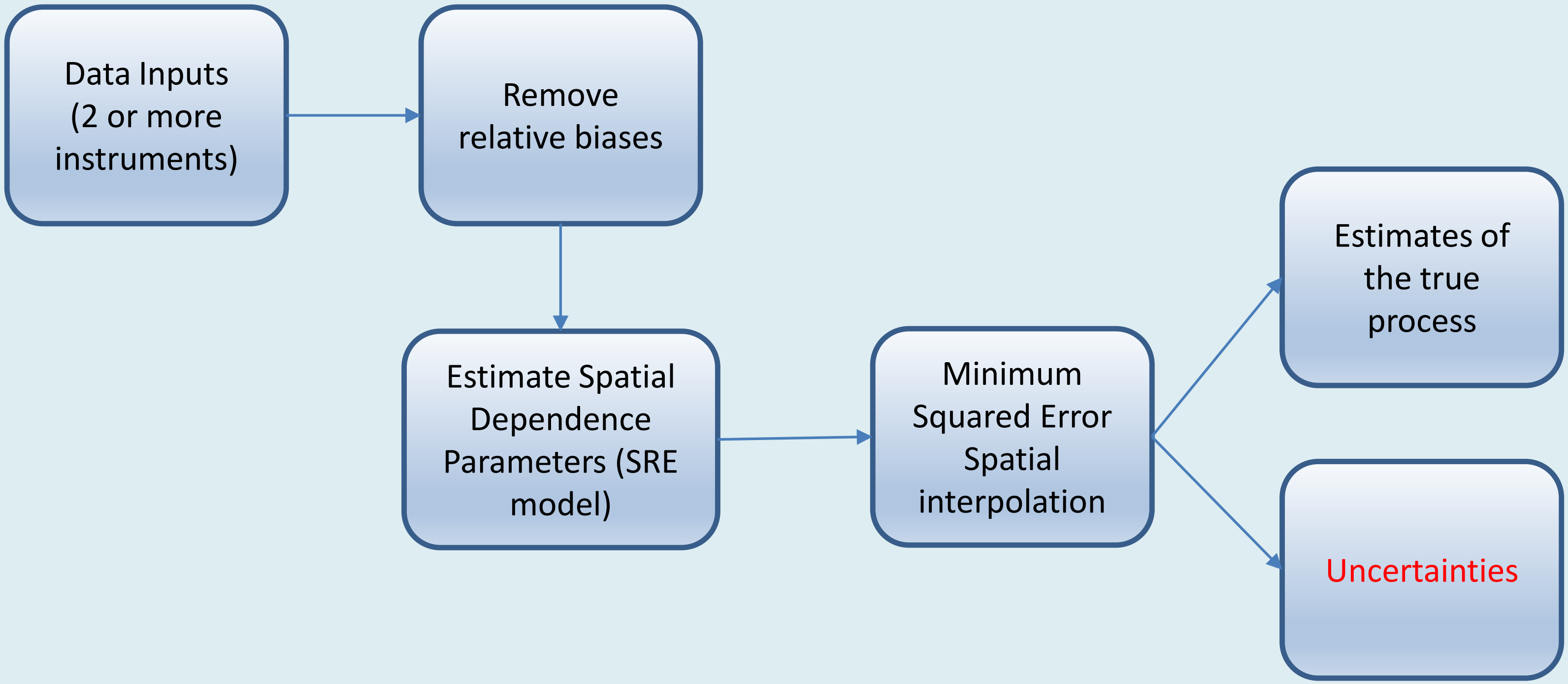



Example of basis function in SRE model

- **The methodology accounts for spatial dependence, inter-instrument dependence, and different measurement error characteristics (bias and uncertainty)**

***Peter Kalmus, JPL***

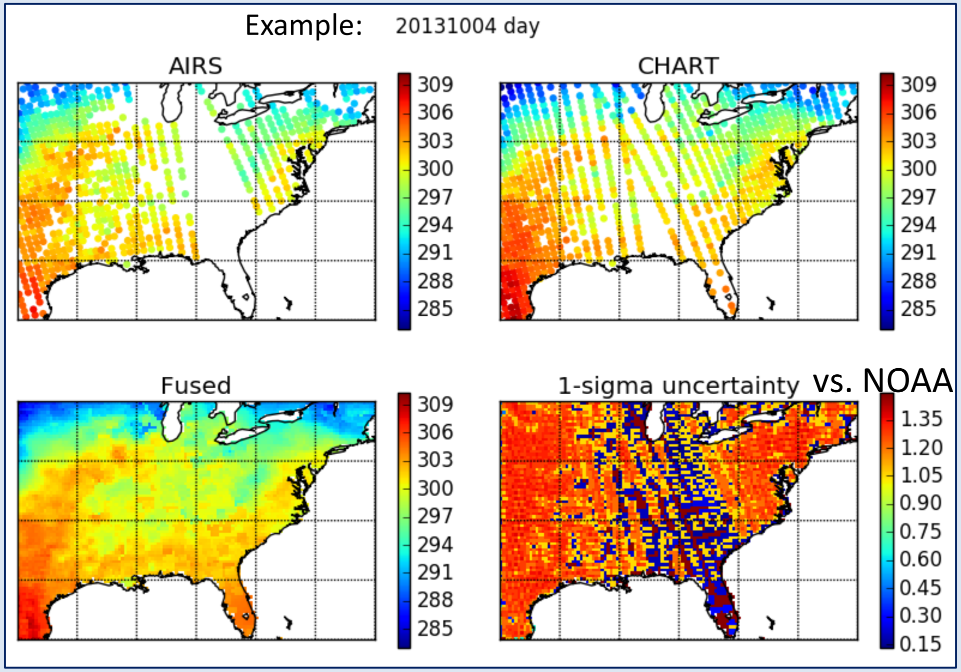
# Algorithm flowchart



# Data Fusion of AIRS + CrIS Near-surface Temperatures

**Fusion done on a daily basis, separately for day & night, over Eastern U.S.**

- **AIRS v6 support product + CrIMSS CHART support product.**
- **Uses NOAA ISD (Integrated Surface DB) to estimate input errors.**
- **Could extend to other instruments (e.g. IASI) and to global domain.**
- **For climate model evaluation, applications (heat waves, drought...).**

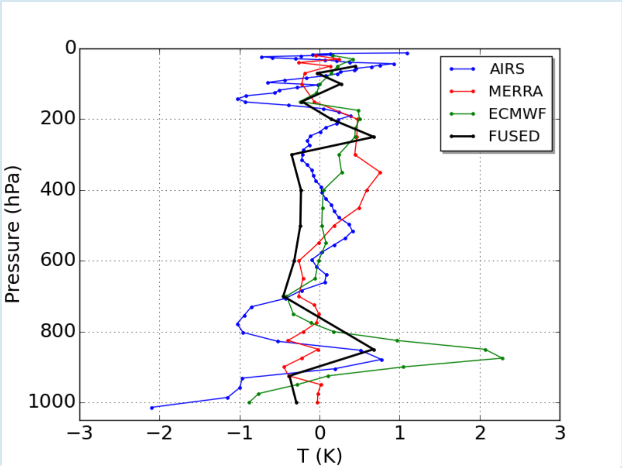


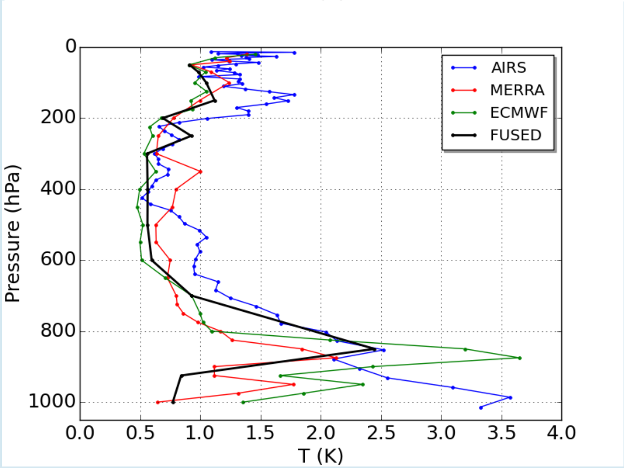

***Peter Kalmus, JPL***

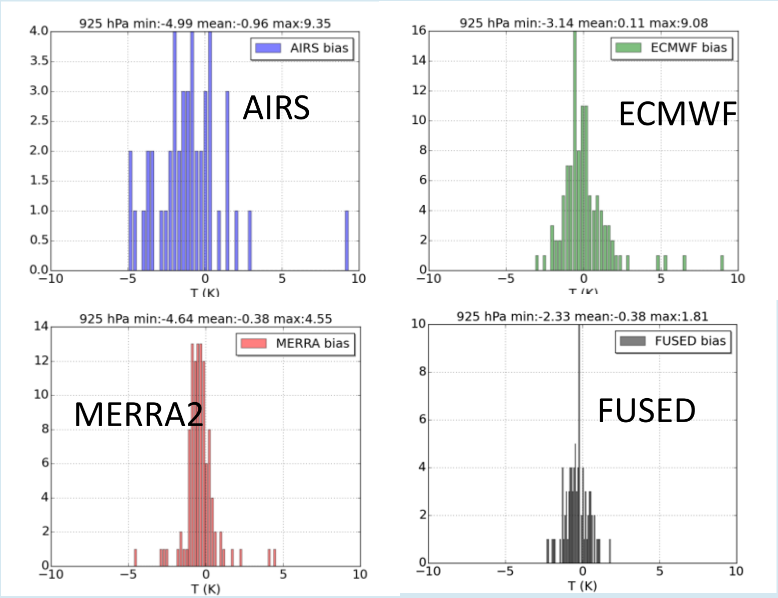
# Data Fusion of Temperature Profiles
# *proof of concept*

**Fusion of 3 data sets: AIRS+ECMWF+MERRA2**

- **Levels fused separately, T, q fused separately (for now).**
- **July 2013, 10N—40N, 130W—160W.**
- **Errors estimated from MAGIC radiosondes**
- **Next step: fusion in subtropical oceans.**
  - **Estimate errors using MAGIC + machine learning.**




**Bias histograms at 925 hPa**

***Peter Kalmus, JPL***

# Data Fusion References


- **Cressie, Noel, and Gardar Johannesson. "Fixed rank kriging for very large spatial data sets."** ***Journal of the Royal Statistical Society: Series B (Statistical Methodology)*** **70.1 (2008): 209-226.**

- **Nguyen, Hai, Noel Cressie, and Amy Braverman. "Spatial statistical data fusion for remote sensing applications."** ***Journal of the American Statistical Association*** **107.499 (2012): 1004-1018.**

- **Nguyen, Hai, et al. "Spatio-temporal data fusion for very large remote sensing datasets."** ***Technometrics*** **56.2 (2014): 174-185.**

- **Nguyen, Hai, Noel Cressie, and Amy Braverman. "Multivariate spatial data fusion for very large remote sensing datasets."** ***Remote Sensing*** **9.2 (2017): 142.**

- **Kalmus, Peter, Hai Nguyen, Amy Braverman, Yuliya Marchetti, and Evan Fishbein., "Spatial statistical data fusion of AIRS and CrIS near surface temperature."** ***In preparation.***

# Summary and Conclusions

**Summary**

- **More than a decade of overlapping hyperspectral IR sounder coverage.**
  - **Even longer for microwave instruments.**
- **Still *many* issues to be resolved to merge L2 and L3.**
- **A long history of data fusion in the statistical literature.**
  - **E. g. kriging.**
- **Making progress on how to convey common information.**

**Conclusions**

- **Consistent retrieval algorithm(s) will simplify data fusion.**
  - **This will require L2 developed to characterize long-term behavior.**